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# REPORT ON PHASE IIb

# GEOCHEMICAL DISPERSION OF ELEMENTS IN THE ROCKY MOUNTAIN ARSENAL AREA

A SPRING FOLLOW-UP ON THE FALL PHASE IIa PROGRAM

Prepared for

THE DEPARTMENT OF THE ARMY

By

IntraSearch, Inc.
Denver, Colorado

September, 1976

Dr. Paul B. Trost



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THE OBJECTIVE OF THE SPRING PROGRAM WAS TO DETERMINE IF THERE ARE SIGNIFICANT SEASONAL VARIATIONS IN TRACE ELEMENT CONCENTRATIONS IN THE SOIL, WATER, AND PLANT SAMPLES.

A SIGNIFICANT SEASONAL VARIATION WAS OBSERVED FOR CONDUCTIVITIES IN BOTH SURFACE AND GROUND WATER. AN INCREASE IN AS IN GROUND WATER WAS OBSERVED IN THE SPRING, AND DIMP CONCENTRATIONS ARE TIME DEPENDENT.

THE CONCENTRATIONS OF HG, CL, AND CA IN SOILS DECREASED IN THE SPRING. NO SIGNIFICANT SEASONAL EFFECT WAS OBSERVED FOR MG AND SO4. CU CONCENTRATIONS INCREASED IN COTTONWOOD TWIGS IN THE SPRING. THIS DOCUMENT CONSISTS OF TWO PARTS: PART 1 TEXT, AND REDUCED COPIES OF 10 MAPS. PART 2 INCLUDES 11 FULL SIZE MAPS.



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## RESULTS AND CONCLUSIONS

Phase IIb was conducted during late May to early July, 1976, as a follow-up program to the fall sampling (Phase IIa). The object of the spring program was to determine if there are significant seasonal variations in trace element concentrations in the soil, water, and plant entities. Sampling was restricted to those areas known to contain anomalous concentrations of trace elements and compared to those areas of similar geologic setting but removed from any possible influence of Arsenal activities.

Results of the spring sampling program were compared to the fall sampling program. A significant seasonal variation was observed for conductivities in both surface and groundwater samples. Lower spring conductivities were observed in all cases except for those wells located close to Reservoir F. In these wells the concentrations were found to increase. This increase in conductivities again suggests Reservoir F is leaking. Previous studies by Trost have shown the southeast corner to be the major source of the leakage.

Arsenic was again found in one well on the Arsenal ground. Increase in the arsenic content was observed in the spring sampling as compared to the fall sampling. This increase should be expected due to a lowering of pH and temperature which would increase the solubility. Arsenic dispersion was similar to that observed in the fall program, being restricted to only one well.

A very shallow well ($\approx$10 ft) located in Mr. Land's wheatfield, was found to contain anomalous DIMP but no DCPD. The conductivity was also extremely high in this shallow aquifer. Presence of DIMP in this well suggests a RMA source for a portion of the water traversing his wheatfield. Past studies by Trost and others have shown a close correlation exists between DIMP and Cl. Thus at least a portion of the high salt content in Mr. Land's field is due to RMA sources, however the relative

amounts due to RMA versus natural sources is difficult to assess. A resampling of the field well showed DIMP concentration levels to be highly time dependent. The lack of DCPD in this shallow well, coupled with the high DIMP concentration again suggests different dispersion paths for these two contaminants is operating. In addition, different sources and/or time of influx may be present.

Both Mr. Larry Land's and Jim Land's wells were also sampled. These wells were not made available for sampling last fall during the Phase IIa program. No anomalous copper, arsenic or conductivities were found in Mr. Larry Land's well. Mr. Jim Land had two wells, both of which were sampled, a deep well ($\approx$350 ft.) and a shallow well ($\approx$100 ft.). The deep well showed background concentrations of copper, arsenic, and conductivity. The shallow well showed a threshold value of copper. No anomalous arsenic, mercury or conductivity was observed in this well.

Significant seasonal variations were observed in the concentration levels of mercury, chloride and calcium, in the soils of both Land's field and the control field south of the arsenal. This decrease is due to higher water table coupled with downward infiltration and leaching of the salts by the spring rains. No significant seasonal effect was observed for magnesium or sulfate. It is therefore imperative that all soil sampling data be interpreted utilizing this seasonal concentration variance.

Significant seasonal variations were also observed in the concentration levels of copper in cottonwood twigs. In general the copper concentration was found to increase due to the larger volume of sap running through the twigs in the spring. Mercury concentration levels were, however, found to decrease as compared to the fall concentration levels. This decrease is probably related to a decrease in the chloride content in ground waters by normal dilution. Since mercury would migrate as a chloride complex its

concentration levels in the water, and thus available to the plant, would decrease.

## INTRODUCTION

During the summer of 1975 IntraSearch was retained by the Rocky Mountain Arsenal to conduct a remote sensing program to determine if Reservoir F was leaking (Phase I). This study resulted in the definition of areas containing vegetative stress. To evaluate these areas of vegetative stress a two phase geochemical program was initiated. Phase IIa was conducted in October through December, 1975, with samples of soil, plants, surface waters, groundwaters, and reservoir waters, collected and geochemically evaluated. Results are contained in a report dated March 1976 by IntraSearch. Phase IIb was initiated in late May, 1976. Again soil, plants, surface waters and groundwaters were collected and have been geochemically evaluated. Results of the two phases have been interpreted and compared to determine if significant seasonal variations are present.

Seasonal variances could be present due to the following factors:

1. Higher goundwater table resulting in:
   a. Different dispersion paths
   b. Dissolution of contaminants contained in the soil above the normal water table level
   c. Lower temperatures of the unconfined aquifer resulting in changes in solubilities of some contaminants, especially arsenic compounds.
2. Recharge of potentially contaminated aquifers at different sites than during the summer/fall months.
3. Ponding in Reservoir A, followed by downward percolation through contaminated sediments and entering the groundwater system.
4. Northward dispersion of potentially contaminated water as a surge or front. This could result in highly anomalous concentrations in certain wells for a relatively short time period.

Dr. Paul B. Trost, a geochemist with Martin-Trost Associates, was retained by IntraSearch to conduct both programs.

## OBJECTIVES

The objectives of Phase IIb were to determine if seasonal variations in temperature, groundwater levels and spring recharge of the shallow aquifer would have a significant effect on concentration levels of trace and major elements in the soil, plants and water. Sample sites selected in Phase IIa were resampled in a similar manner and re-analyzed by the same commercial laboratory utilizing the same digestion and analytical techniques.

Objectives to be specifically accomplished were:

1. Determine if Reservoir F is leaking.
2. Determine if Mr. Land's wheatfield in S/2, Sec. 14, T2S, R67W, contains anomalous concentrations of elements relatable to present or past Arsenal activities and if these concentrations are variable due to seasonal effects.
3. Compare the concentrations of trace and major elements from Phase IIa and Phase IIb.
4. Develop additional data for a uniform sampling schedule as related to any seasonal variances.

## FIELD AND ANALYTICAL METHODS EMPLOYED

All sampling and analysis were conducted in locations and manners as those obtained for Phase IIa. This was done to insure any variances observed were relatable to seasonal effects.

Please refer to the March 1976 report by Trost for a complete description of sampling and analytical techniques employed during this phase.

Sampling was restricted to those areas which would be the most affected by seasonal variations and which would yield the most information regarding the integrity of Reservoir F, the salt content of Land's wheatfield, and effects of spring recharge in the unconfined aquifer.

Samples were collected from Land's wheatfield and from a control wheatfield south of the arsenal, located in NW/4 Sec. 17, T3S, R66W.

Groundwater samples were collected from most of the wells previously sampled during the fall/winter of 1975.

Cottonwood twigs were also resampled in order to compare any concentration changes in the twigs at the end of the growing season (fall/winter) as compared to the start of the growing season (spring/summer).

## SURFACE WATER SAMPLING RESULTS

Surface water samples were collected at sites previously sampled in Phase IIa. Sample results are tabulated in Appendix I. Results for the conductivity at each site has been plotted on Map I. Dispersion maps have not been prepared for arsenic or copper due to their lack of variance from the previous results of Phase IIa.

Conductivities of surface waters were generally lower by 10-15% as compared to the fall sampling. Sample sites of First Creek upstream and downstream of the plant's surface drainage ditch showed no change in conductivities. Thus water discharging from the plant's area at the time of the sampling was apparently only surface water. As was previously noted in Phase IIa, the surface waters show an increase in conductivity north of Reservoirs A and F as shown on Map I.

No significant changes in copper concentrations were observed. In general the spring values were slightly higher however most changes are within the reproducibility of the analytical method employed. Thus no statistically significant seasonal fluctuations for copper in surface waters were observed.

Mercury was not analyzed since the only anomalous concentrations observed in the fall sampling were from waters entering the Arsenal grounds from the Montbello area. No waters containing anomalous concentrations of mercury were found exiting the Arsenal grounds to the north.

The caustic pit, which previously contained anomalous arsenic in its standing waters, was not sampled.

## GROUNDWATER SAMPLING RESULTS

Groundwater (well water) samples were collected from most wells previously sampled during the fall of 1975. The purpose of the spring sampling was to determine if significant seasonal variances are present.

Sample results are tabulated in Appendix I and on Maps IIb, IIc.

Map IIb, copper in groundwater, showed no major concentration variances except for well 12D-4, which is located south or upstream of RMA. This particular shallow aquifer is tapped by two different wells located a few hundred feet apart. The well sampled in the fall was not available in the spring, thus the second well was sampled. This large variance reflects different conditions in the plumbing and not the aquifer. In general most wells showed a slightly higher copper concentration, however this may be due to an analytical error as compared to a seasonal variance, especially since most values are quite close to the detection limit.

In this spring sampling program additional wells were sampled which were not previously sampled during the fall program. These were Larry Land's well (LL1), J. Land's wells (JL1, J12) and a shallow well located in the middle of Mr. Land's wheatfield north of the Arsenal (LLW). Larry Land's well (LL1) showed no anomalous copper concentration as compared to other wells in the area. Mr. J. Land's shallow well (JL2) did however show a copper concentration significantly higher than that of his deeper well (JL1). A difference in trace element concentrations between two hydrologically separated aquifers is not unusual. However JL2 should be resampled after being pumped for a minimum of 30 minutes to insure a representative sample. The sample collected in this study was obtained after 10 minutes of pumping. These results should then be compared to copper concentrations from wells tapping the same shallow aquifer and located south of the Arsenal.

Sample LLW located in Mr. J. Land's wheatfield, was obtained from a depth of 5 feet below the surface by bailing. This well had extremely high salt content. This high salt content would allow greater concentrations of copper to remain in solution through the formation of a complex chloride anion such as $CuCl_2^-$, ($K = 10^{-5.60}$). Thus interpreting the total copper concentration without considering its geochemical environment would be misleading. This shallow well was sampled on two different days, one in late May and again in mid June. A split of this sample was submitted to RMA for analysis of DIMP and DCPD. Results are shown below.

| Date | DIMP, ppb | DCPD, ppb | pH | Conductivity |
|---|---|---|---|---|
| 28 May 1976 | 2100 | 0 odor | 7.78 | 7620 |
| 22 June 1976 | 880 | <10 | 7.15 | not analyzed |

This well should be closely monitored to determine if DCPD, dieldrin, endrin, or aldrin are ever present. Since this initial analysis has not shown DCPD to be present a different source and/or dispersion path is present for these two contaminants. The extremely high conductivity is predominately due to high chloride and sulfate concentrations with the chloride being the major anionic species. This common association of chloride and DIMP has been previously noted in both the Reservoir A and F areas. A correlation plot of DIMP vs. Chloride (Figure I) shows a fairly close relationship between these two parameters. Furthermore a previous report by Trost has shown a correlation coefficient of 0.8577 between DIMP and chloride. In 1956, Petri and Smith showed a very high chloride concentration was present in the immediate vicinity of Land's wheatfield; the source of which they attributed to the RMA area. The presence of DIMP in Land's field, coupled with its correlation with chloride, suggests a portion of the chloride content of Land's field is due to RMA sources. The relative amounts of the chloride concentration which can be ascribed to RMA versus natural sources is very difficult to assess with the present information.

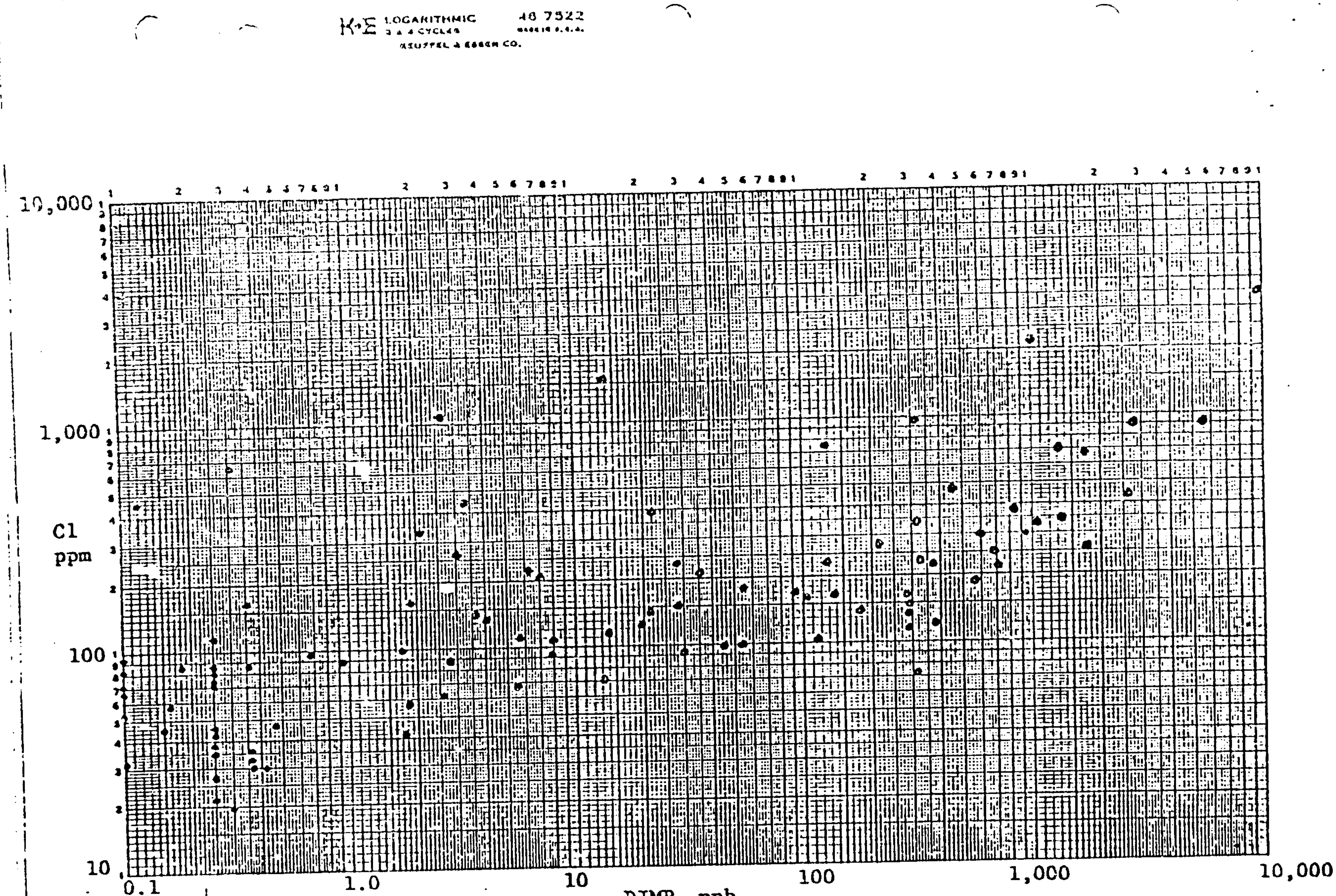


FIGURE I

CORRELATION PLOT OF CHLORIDE vs DIMP
Rocky Mountain Arsenal Area

data from RMA sources

RSH 918

BN 71 FS PN 35 PD 174753/1-102 FL Treatment Plant

No arsenic was observed in any of the wells sampled except for RMA well no. 40. In this well, the arsenic content showed a 50% increase over the fall sampling. It is interesting to note that the conductivity showed a 20% decrease as compared to last fall. It therefore appears that either additional arsenic is leached from above the normal water table layer by spring rains and subsequent infiltration or that a change in ground water temperature and/or pH may be important. Arsenic compounds such as $As_2O_5$, and $Ba_3(AsO_4)_2$ are known to be more soluble in cold water than in warm water. Thus temperature and pH should be monitored in all future sampling programs. As was previously noted in the fall sampling, the high arsenic concentrations in well no. 40 showed very restricted dispersion since other nearby wells were not found to contain anomalous arsenic concentrations.

Conductivities of the unconfined near-surface aquifer generally showed a 10-20% decrease except for those wells located close to Reservoir F (see Map IIc). These wells showed up to 50% increase in their conductivities as compared to last fall. During the winter very high water levels were observed in Reservoir F. This resulted in both splash-over and infiltration through the dike and into the southeast corner. In addition, portions of the liner generally located above the normal water level were submerged. Previous studies by Trost, have shown a poor liner integrity exists in the southeast corner. This has resulted in contaminants entering the shallow aquifer from this area. Thus aqueous solutions from Reservoir F could enter the shallow ground water system both through the southeast corner area and possibly through the upper levels of the liner. Only very minor changes in conductivities were observed for the deeper aquifers such as wells Wt 3D-5, 6, 7, and JL1. Thus conductivity shows a significant seasonal variation for shallow aquifers but little for deeper aquifers (400 ft.). This seasonal variation may be useful in discriminating between shallow and deep aquifers and must be considered in future sampling programs and interpretation.

No significant variance in the dispersion paths have been noted between the spring and fall sampling thereby suggesting higher ground water levels do not influence dispersion directions.

SOIL SAMPLING RESULTS

Soil samples were collected from Land's wheatfield north of the arsenal and from the wheatfield south of the arsenal. Soils samples from both the A and B soil horizons were collected in the same areas as previously sampled last fall. Sample results are presented on maps with separate maps for the A and B soil horizons. The mean and standard deviations for each sample area were calculated and are shown in Appendix II.

Descriptions of the areas sampled are:

AO - E14 Land's wheatfield located in SW/4, Sec. 14, T2S, R67W.

AAO - AE4-5 Area located south of the Arsenal in the NW/4 Sec. 17, T3S, R66W.

Mercury concentrations in both the A and B soil horizons were determined. Results are shown on Maps IIIcA and IIIcB. In general no significant seasonal variations in dispersion patterns were observed in the two wheatfields. It is noteworthy, however, that Land's wheatfield again showed a slightly elevated mean concentration level as compared to the wheatfield south of the Arsenal. This minor difference in the means is however negated by the large standard deviations.

There does exist a seasonal variance in the concentration levels for both data sets, with the spring sampling showing significantly less mercury content than the fall sampling. This is probably due to summer evaporation and concentration of mercuric salts from the near surface chloride-rich groundwater. This conclusion is further documented by the slightly higher mercury concentrations observed in the salt-rich B soil horisons. It is therefore imperative that all sampling be interpreted with regard

to season. Failure to do so could result in a false seasonal anomaly. For example the fall mean mercury concentration for Land's wheat-field of 20.81 ppb does indeed appear anomalous compared to the spring value for the southern wheatfield of 8.10 ppb; whereas the fall mercury concentration in the southern wheatfield is 14.25 ppb which is comparable to the 20.81 ppb in Land's field.

The salt-rich B soil horizon contains slightly higher mercury concentrations than does the organic-rich A soil horizon. Apparently in areas of very high salt content, the formation of complex sulfate and chloride anions is a more controlling factor than the humic acid-mercury relationships.

<u>Chloride</u> content in soils is shown on Maps IIIdA, IIIdB. A significant seasonal variation in concentration levels was observed between the fall and spring sampling. The spring concentration levels are approximately 50% lower than the fall levels. This decrease is a result of downward flushing and mobilization by the spring rains and runoff. Thus it is again imperative that all soil sampling results be compared during the same seasonal period.

No major change in the dispersion patterns was observed between the spring and fall sampling periods. The low-lying recent alluvium areas in both wheatfields still contain the highest relative concentrations.

<u>Sulfate</u> content in soils is shown in Map IIIeA and Map IIIeB. No significant seasonal variation in concentration levels was observed between the spring and fall sampling. This is due to the insolubility of $CaSO_4$. Thus spring rains and runoff do not dissolve the $CaSO_4$ whereas they do dissolve and mobilize the more soluble chloride salts e.g. $CaCl_2$, NaCl. Concentration levels in both Land's field and the field south of the Arsenal are extremely similar to the fall results. The general distribution patterns are also very similar to the fall results.

Calcium content in soils is shown on Map IIIfA and Map IIIfB. A significant variation in the calcium content of the B soil horizon was observed with the spring sampling showing lower concentrations. The A soil horizon did not show a significant change from the fall results. In the A soil horizon, the calcium is predominately present as the insoluble $CaSO_4$, whereas in the B soil horizon calcium is immobilized by both $CaSO_4$ and clay adsorption. Thus spring flushing results in a decrease in calcium content due to desorption from the clays; whereas the insolubility of $CaSO_4$ in the A horizon shows no seasonal affect.

No significant variation in the dispersion pattern was observed for either the A or B soil horizons in the spring or fall sampling.

Magnesium content in soils is shown on Map IIIgA and Map IIIgB. No significant changes were observed in either the concentrations or dispersion patterns of magnesium and the A and B soil horizons. This probably reflects absorption and adsorption of magnesium onto the clays with relatively minor amounts available as soluble sulfate or chloride salts which would be subject to seasonal variations.

## VEGETATIVE SAMPLING RESULTS

Cottonwood twigs were resampled in areas known to contain anomalous copper and mercury concentrations as delineated in the fall sampling program. These samples were compared with other cottonwood twigs obtained upstream from all RMA manufacturing activities. Samples were collected and analyzed in the same manner as the fall program. Tabulated results are in Appendix I.

Copper concentrations in twigs showed a slight increase in the spring sampling as compared to the fall sampling. This slight increase is a seasonal effect probably due to a large volume of sap running through the recent twigs to the new leaf growth. Although the copper concentration in the sap would probably be similar to the fall concentrations, the greater volume of flow would result in more copper being removed by the twig, and hence a higher twig copper concentration.

All areas that were anomalous in the fall program were also found anomalous in the spring program. In one area (Sample No. 12N-5) along First Creek the copper concentration was found anomalous in the spring sampling but not in the fall. This area should be resampled to insure no contamination was present. If the results are reproducible a source of copper such as the trailer court seepage lagoon located southeast of the Arsenal, would be suspected. No copper source due to RMA activities is reasonable for this area upstream of the plant's location.

A composite twig sample from numerous trees was taken from the transplanted cottonwoods along the north boundary near the bog. This sample was taken to provide a base line or background value for future sampling programs. The copper concentration was 13 ppm or average for those samples upstream of the plants area.

No geochemical map was prepared for copper in twigs since no change was observed in dispersion patterns.

Mercury concentrations in cottonwood twigs showed a slight decrease as compared to the fall sampling results. This decrease is probably related to the decreased conductivity in the ground water during the spring. The decreased conductivity would reflect a decreased chloride concentration. Thus the formation of a stable mercury chloride complex would be inhibited and less mercury would be available in the ground water for the roots to assimilate.

The anomalous mercury concentrations observed in the fall sampling along the southern boundary of RMA was not observed in the spring program. This may be due to a decrease in mercury concentration in the effluents of the Montbello industrial area or less mercury mobilization due to a lower chloride content. No other significant changes in the dispersion pattern were noted. Due to the lack of significant dispersion changes no geochemical map has been compiled for mercury in cottonwood twigs.

## RECOMMENDATIONS

Based on the results of Phase IIa and Phase IIb the following recommendations are made:

(1) That the temperature and pH be measured at each well sampled to aid in data interpretation.

(2) That Mr. Jim Land's shallow well be resampled after pumping for 1 hour to insure a fresh sample.

(3) That all data be collected, interpreted, and compared during the same season to avoid seasonal variations.

(4) That specific wells e.g. RMA no. 40, LLW, 118, RMA no. 60, 20N-1, 20N-2 be monitored and utilized to interpret seasonal fects on concentration levels.

(5) That a sampling program be developed to determine if high concentrations of DIMP, DCPD, etc. move as a surge front. This will aid in predicting when and where high concentration levels of contaminants will appear.

(6) That a correlation plot of DIMP vs Cl be prepared on a seasonal data base and utilized to interpret what relative amount of chloride, due to RMA sources, is present in Land's field in the shallow aquifer.

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September 29, 1976
Job: 6F27

Dr. Paul B. Trost
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REPORT OF ANALYSES

| Sample (soils) | Ca, % | Mg, % | Hg, ppb | $SO_4^{=}$, μeq/gm | $Cl^-$, μeq/gm |
|---|---|---|---|---|---|
| AA 0 | 0.43 | 0.29 | 10 | 36 | 6 |
| 0B | 0.45 | 0.50 | 10 | 16 | 1 |
| 1.5 | 0.43 | 0.35 | <10 | 6 | 4 |
| 1.5B | 0.48 | 0.45 | 10 | 24 | 5 |
| 3.0 | 0.72 | 0.44 | 10 | 7 | 10 |
| 3.0B | 0.69 | 0.62 | 15 | 34 | 14 |
| 4.5 | 0.32 | 0.34 | <10 | 32 | 1 |
| 4.5B | 0.35 | 0.38 | <10 | <1 | 2 |
| AB 0 | 0.68 | 0.34 | 15 | 49 | 6 |
| 0B | 0.47 | 0.43 | <10 | 7 | 1 |
| 1.5 | 0.37 | 0.37 | <10 | 7 | 2 |
| 1.5B | 0.36 | 0.36 | <10 | 7 | 2 |
| 3.0 | 0.53 | 0.35 | <10 | 40 | 9 |
| 3.0B | 0.42 | 0.54 | <10 | 18 | 6 |
| AC 0 | 0.41 | 0.35 | <10 | 5 | 9 |
| 0B | 0.55 | 0.56 | <10 | 32 | 39 |
| 1.5 | 0.39 | 0.32 | <10 | 4 | 4 |
| 1.5B | 0.49 | 0.41 | <10 | 10 | 3 |
| 3.0 | 0.96 | 0.61 | 20 | 45 | 9 |
| 3.0B | 0.70 | 0.79 | 20 | 44 | 8 |
| 4.5 | 0.80 | 0.53 | 30 | <1 | 3 |
| 4.5B | 5.5 | 0.58 | 15 | <1 | 2 |
| AD 0 | 0.40 | 0.26 | <10 | <1 | 4 |
| 0B | 0.38 | 0.33 | <10 | <1 | 15 |
| 1.5 | 0.43 | 0.39 | <10 | <1 | 3 |
| 1.5B | 0.47 | 0.41 | <10 | <1 | 16 |
| 3.0 | 1.1 | 0.48 | 15 | 28 | 8 |
| 3.0B | 0.70 | 0.62 | 15 | 6 | 3 |
| 4.5 | 0.43 | 0.43 | 10 | 8 | 2 |
| 4.5B | 0.48 | 0.58 | 15 | 6 | 2 |

ANALYTICAL SERVICES AND RESEARCH

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| Sample (Soils) | Ca, % | Mg, % | Hg, ppb | $SO_4^{=}$, µeq/gm | $Cl^{-}$, µeq/gm |
|---|---|---|---|---|---|
| AE O | 1.4 | 0.45 | 15 | 54 | 12 |
| OB | 0.60 | 0.59 | 10 | 10 | 2 |
| 1.5 | 0.41 | 0.34 | 10 | 3 | 2 |
| 1.5B | 0.66 | 0.56 | 25 | 16 | 7 |
| 3.0 | 0.40 | 0.33 | 10 | 2 | 1 |
| 3.0B | 0.55 | 0.46 | 15 | 4 | 5 |
| 4.5 | 0.31 | 0.25 | <10 | <1 | 1 |
| 4.5B | 0.47 | 0.39 | 10 | 7 | 3 |
| A O | 0.58 | 0.43 | <10 | 3 | <1 |
| OB | 0.43 | 0.45 | <10 | 4 | 1 |
| 2 | 0.27 | 0.46 | 20 | 4 | <1 |
| 2B | 0.32 | 0.57 | 20 | 1 | <1 |
| 4 | 0.32 | 0.53 | 25 | 3 | <1 |
| 4B | 0.45 | 0.67 | 20 | 3 | <1 |
| 6 | 0.33 | 0.54 | 10 | 8 | 2 |
| 6B | 0.35 | 0.47 | 10 | 8 | 2 |
| 8 | 0.22 | 0.44 | 10 | 2 | 1 |
| 8B | 1.3 | 0.84 | 15 | 500 | 7 |
| B O | 0.43 | 0.33 | <10 | 3 | <1 |
| OB | 0.43 | 0.39 | 10 | 2 | <1 |
| 2 | 0.34 | 0.45 | 15 | 3 | <1 |
| 2B | 6.1 | 0.71 | 15 | 28 | <1 |
| 4X | 0.45 | 0.54 | 15 | 110 | 20 |
| 4BX | 1.1 | 0.86 | 20 | 470 | 12 |
| 6X | 0.46 | 0.43 | 15 | 130 | 12 |
| 6BX | 0.59 | 0.72 | 15 | 210 | 17 |
| 8X | 0.50 | 0.45 | 15 | 130 | 10 |
| 8BX | 0.55 | 0.64 | 10 | 120 | 8 |
| 10 | 0.34 | 0.45 | 15 | 2 | <1 |
| 10B | 0.58 | 0.64 | 20 | 0 | <2 |
| C 2 | 0.32 | 0.50 | 15 | 1 | <1 |
| 2B | 0.31 | 0.50 | 15 | 2 | 1 |
| 4 | 0.47 | 0.55 | 15 | 130 | 6 |
| 4B | 4.8 | 0.80 | 15 | 1100 | 12 |
| 6 | 0.39 | 0.43 | 15 | 50 | 18 |
| 6B | 0.46 | 0.60 | 10 | 88 | 12 |
| 8 | 0.31 | 0.41 | 15 | 14 | 1 |
| 8B | 0.47 | 0.76 | 35 | 49 | 8 |
| 10 | 0.37 | 0.52 | 10 | 3 | <1 |
| 10B | 0.45 | 0.49 | <10 | 6 | <1 |

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Job: 6F27

| Sample (soils) | Ca, % | Mg, % | Hg, ppb | $SO_4^{=}$, µeq/gm | $Cl^-$, µeq/gm |
|---|---|---|---|---|---|
| C 12 | 0.31 | 0.49 | 15 | 2 | <1 |
| 12B | 1.1 | 0.73 | 10 | 4 | <1 |
| 14 | 0.36 | 0.50 | 15 | 3 | <1 |
| 14B | 0.42 | 0.60 | 20 | 4 | <1 |
| D 2 | 0.32 | 0.49 | 10 | 1 | <1 |
| 2B | 0.33 | 0.50 | <10 | <1 | <1 |
| 4 | 0.28 | 0.44 | <10 | <1 | <1 |
| 4B | 0.30 | 0.47 | 10 | 1 | <1 |
| 6 | 0.38 | 0.48 | <10 | 2 | <1 |
| 6B | 3.0 | 0.71 | 10 | 29 | 2 |
| 8 | 0.35 | 0.40 | 10 | 25 | 10 |
| 8B | 0.34 | 0.45 | 10 | 13 | 7 |
| 10 | 0.34 | 0.46 | 10 | <1 | <1 |
| 10B | 0.53 | 0.68 | 30 | 1 | <1 |
| 12 | 0.30 | 0.41 | <10 | <1 | <1 |
| 12B | 0.39 | 0.54 | <10 | 2 | <1 |
| 14 | 0.25 | 0.37 | <10 | 2 | <1 |
| 14B | 0.31 | 0.50 | 10 | 3 | <1 |
| E 2 | 0.27 | 0.46 | <10 | 3 | 1 |
| 2B | 0.32 | 0.58 | <10 | 4 | 2 |
| 4 | 0.28 | 0.48 | 10 | 2 | 1 |
| 4B | 0.38 | 0.84 | <10 | 12 | 2 |
| 6X | 0.42 | 0.53 | <10 | 57 | 22 |
| 6BX | 0.39 | 0.36 | <10 | 60 | 27 |
| 8 | 0.38 | 0.53 | <10 | 2 | <1 |
| 8B | 0.48 | 0.70 | 10 | 2 | <1 |
| 10 | 0.43 | 0.69 | 10 | 2 | 1 |
| 10B | 0.50 | 0.66 | 10 | 2 | <1 |
| 12 | 0.27 | 0.39 | <10 | 3 | <1 |
| 12B | 0.33 | 0.50 | 15 | 2 | <1 |
| 14 | 0.43 | 0.47 | <10 | 2 | <1 |
| 14B | 0.46 | 0.48 | <10 | 2 | <1 |

ANALYTICAL SERVICES AND RESEARCH

GEOLABS
1100 Simms Street
Lakewood, Colorado
Phone (303) 233-8155

Mailing Address:
P.O. Box 702
Edgemont Branch
Golden, Colorado 80401



Job: 6F27

GEOLABS

A DIVISION OF
NATURAL RESOURCES LABORATORY, INC.

| Sample (water) | Cu,ppb | As,ppb | K,µmho/cm |
|---|---|---|---|
| 13N-3 | <10 | <10 | 800 |
| -4 | 10 | <10 | 940 |
| 18N-1* | 10 | <10 | 460 |
| -2 | 10 | <10 | 433 |
| -3 | <10 | <10 | 334 |
| -4 | <10 | <10 | 333 |
| -5 | 10 | <10 | 986 |
| [illegible]N-1 | 20 | <10 | 951 |
| -2 | 20 | <10 | 472 |
| -3 | 20 | <10 | 443 |
| -4 | 10 | <10 | 885 |
| [illegible]ON-1 | 10 | <10 | 973 |
| -2 | 10 | <10 | 1930 |
| -3 | 10 | <10 | 1310 |
| -5 | 10 | <10 | 439 |
| 12D-2 | 20 | <10 | 600 |
| -3 | 10 | <10 | 886 |
| -4 | 140 | <10 | 1210 |
| -5 | 10 | <10 | 2020 |
| 24D-2 | 10 | <10 | 780 |
| 2D-4 | 10 | <10 | 830 |
| -5 | <10 | <10 | 359 |
| -6 | 10 | <10 | 625 |
| -7 | 40 | <10 | 357 |
| -8 | 10 | <10 | 1230 |
| 1DC-1 | 20 | <10 | 429 |
| JL-1 | 10 | <10 | 392 |
| 2 | 50 | <10 | 751 |
| 2NP* | - | - | 473 |
| LLW** | 75 | <10 | 7620 |

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GEOLABS

Job: 6F27

A DIVISION OF
NATURAL RESOURCES LABORATORY, INC.

| Sample (water) | Cu,ppb | As,ppb | K,µmho/cm |
|---|---|---|---|
| LL 1*** | 65 | <10 | 481 |
| LL 1*** | 20 | - | - |
| LL 1*** | 20 | - | - |
| 40 | 50 | 3000 | 8040 |
| 41 | 30 | <10 | 3130 |
| 115 | 20 | <10 | 1510 |
| 118 | 30 | <10 | 3990 |
| 119 | 10 | <10 | 1300 |
| 121 | 20 | <10 | 2310 |
| 145 | 20 | <10 | 2250 |
| 3A | 10 | <10 | 1580 |
| 17 | 20 | <10 | 2190 |
| 37 | 20 | <10 | 622 |
| 60 | 20 | <10 | 1820 |
| 62 | 10 | <10 | 1090 |
| WTX 8.1 | 90 | <10 | 645 |

*No acidified sample received
** 2 acidified samples received
*** 3 acidified samples received

| Sample (water) | Hg,ppb | $Cl^-$,ppm (job 6J05) |
|---|---|---|
| JL-1 | <0.1 | 5 |
| -2 | <0.1 | 130 |
| -2NF | - | 32 |
| LLW (1) | 0.1 | 2380 |
| LLW (2) | <0.1 | - |
| LLW (3) | <0.1 | - |
| LL 1 (1) | <0.1 | 20 |
| LL 1 (2) | <0.1 | |
| LL 1 (3) | <0.1 | |

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GEOLABS

Job: 6F27

A DIVISION OF
NATURAL RESOURCES LABORATORY, INC.

| Sample (plants) | Cu,ppm | Hg,ppb |
|---|---|---|
| CT-1 | 29 | 25 |
| 2 | 25 | 20 |
| 3 | 45 | 20 |
| 6 | 10 | <10 |
| 11N-1 | 13 | 20 |
| 11N-2 | 10 | 10 |
| 11N-6 | 9 | <10 |
| 12N-5 | 27 | 20 |
| 17N-4 | 15 | 15 |
| CT-Bog New | 13 | 15 |

Ronald L. Keil

Ronald L. Keil

ANALYTICAL SERVICES AND RESEARCH

# APPENDIX II

## Ca%

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| AAO - AE4-5 | 19 | 0.57 | 0.30 |
| AAOB - AE4-5B | 19 | 0.78 | 1.15 |
| AO - E14 | 32 | 0.36 | 0.08 |
| AOB - E14B | 32 | 0.88 | 1.31 |

## Mg%

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| AAO - AE4-5 | 19 | 0.38 | 0.09 |
| AAOB - AE4-5B | 19 | 0.50 | 0.12 |
| AO - E14 | 32 | 0.47 | 0.07 |
| AOB - E14B | 32 | 0.61 | 0.14 |

## Hg ppb

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| AAO - AE4-5 | 19 | 8.10 | 8.29 |
| AAOB - AE4-5B | 19 | 8.84 | 7.72 |
| AO - E14 | 32 | 9.41 | 6.91 |
| AOB - E14B | 32 | 11.66 | 7.90 |

## $SO_4$ µeg/gm

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| AAO - AE4-5 | 19 | 0.57 | 0.30 |
| AAOB - AE4-5B | 19 | 0.78 | 1.15 |
| AO - E14 | 32 | 0.36 | 0.08 |
| AOB - E14B | 32 | 0.88 | 1.31 |
| AO - E14 | 32 | 0.36 | 0.08 |
| AOB - E14B | 32 | 0.88 | 1.31 |

## Cl

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| AAO - AE4-5 | 19 | 5.05 | 0.20 |
| AAOB - AE4-5B | 19 | 7.16 | 9.04 |
| AO - E14 | 32 | 3.28 | 6.36 |
| AOB - E14B | 32 | 3.64 | 6.27 |

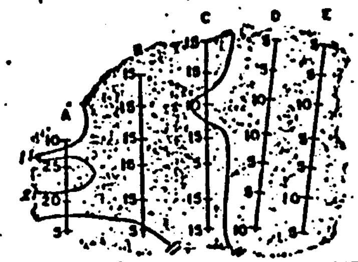
## Cu

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| Water Samples 13N-3 | 44 | 21.84 | 25.78 |

## K

| Sample Nos. | No. of Samples | Mean | Standard Deviation |
|---|---|---|---|
| | 44 | 13.61 | 16.18 |

Proj. 7597 IIb




Scale: 1"= 1000'
Location: SW 1/4 Section 14, T 2 S, R 67 W
Land's wheatfield


Scale: 1"=500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP IIIcA

MERCURY
in
A SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

IntraSearch

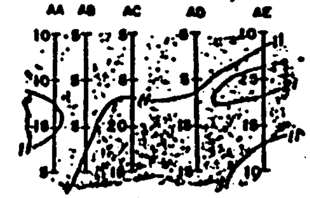
Data prepared by Dr. Paul B. Trost
September 1976

EXPLANATION
Hg, (ppb)

0-10
11-20
21-30
> 30

Proj. 7597 IIb

Scale: 1" = 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield




Scale: 1" = 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP III cB

MERCURY
in
B SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

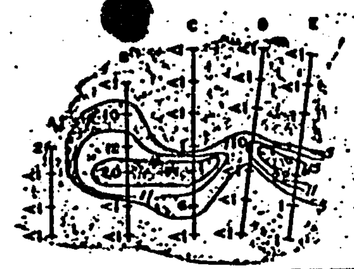
IntraSearch

Data prepared by Dr. Paul B. Trost
September 1976

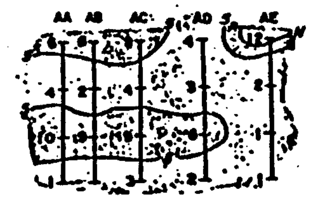
EXPLANATION
H, ppb

0-10
11-20
21-30
>30

Proj. 7597 IIb



Scale: 1"= 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield



Scale: 1"= 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP III d A

CHLORIDE
in
A SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

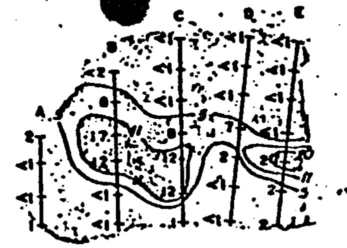
IntraSearch

Data prepared by Dr. Paul B. Trost
September 1976

EXPLANATION
Cl, meq/kg

- <5
- 5-10
- 11-15
- >15

Proj. 7597 IIb



Scale: 1"= 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield

# GEOCHEMICAL MAP III dB

CHLORIDE
in
B SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

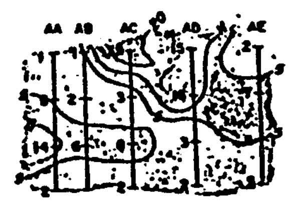
Scale: as noted
Base map from U.S.G.S. topographic maps

IntraSearch

Data prepared by Dr. Paul B. Trost
September 1976

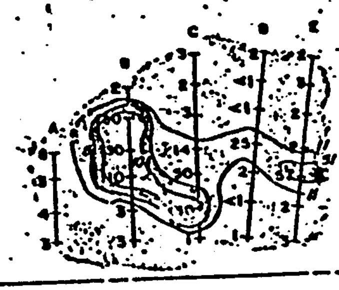
EXPLA NATION
Cl, meq/kg

| | |
|---|---|
| <5 | |
| 5–10 | |
| 11–20 | |
| >20 | |

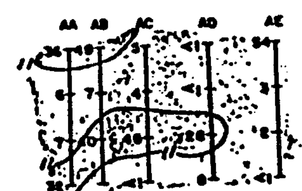


Scale: 1"= 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

Proj. 7597 IIb




Scale: 1" = 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield




Scale: 1" = 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP III-A

SULFATE
in
A SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

IntraSearch

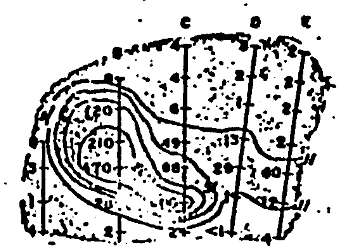
Data prepared by Dr. Paul B. Trost

EXPLANATION

$SO_4$, mg/kg

1–10
11–50
51–100
101–200
>200

Proj. 7597 IIb



Scale: 1" = 1000'
Location: SW 1/4 Section 14, T 2 S, R 67 W.
Land's wheatfield

Scale: 1" = 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP III eB

SULFATE
in
B SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

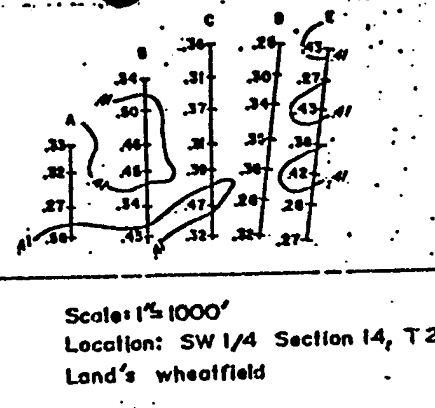
IntraSearch

Data prepared by Dr. Paul B. Trost
September 1976

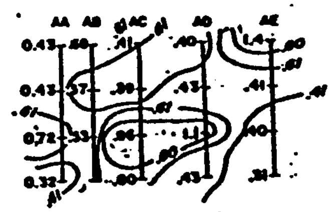
EXPLANATION
$SO_4$, meq/kg

1-10
11-50
51-100
101-200
> 200

Proj. 7597 IIb



Scale: 1" = 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield



Scale: 1" = 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP III f A

CALCIUM
in
A SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

IntraSearch

Data prepared by Dr Paul B. Trost
September 1976

EXPLANATION
Ca, %

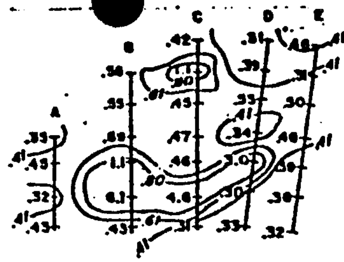
- < 0.41
- .41-.60
- .61-.80
- >.80

RSH 918

NOTICE: If the film image is less clear than this notice, it is due to the quality of the document being filmed

BN 712 FS 2
PN 55 PD 1247521/-100
FL Denver Plant

Proj. 7597 IIb



Scale: 1" = 1000'
Location: SW 1/4 Section 14, T 2 S, R 57 W
Land's wheatfield

Scale: 1" = 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP III f B

CALCIUM
in
B SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

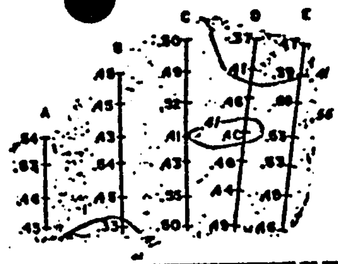
IntraSearch

Data prepared by Dr. Paul B. Trost
September 1973

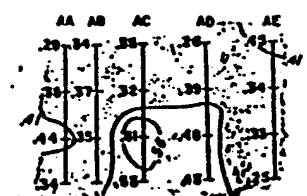
EXPLANATION
Ca, %

| | |
|---|---|
| < 0.41 | |
| .41–.60 | |
| .61–.80 | |
| > .80 | |

Proj. 7597 IIb



Scale: 1" = 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield



Scale: 1" = 500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP IIIgA

MAGNESIUM
in
A SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

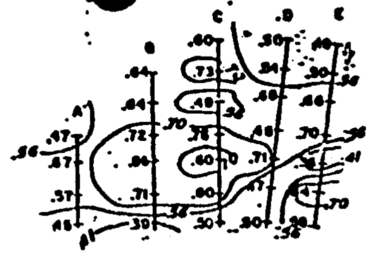
IntraSearch

Data prepared by Dr. Paul B. Trost
September 1976

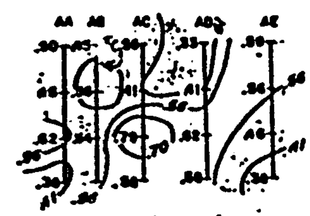
EXPLANATION
Mg %

| | |
|---|---|
| < 0.41 | |
| .41-.55 | |
| .56-.70 | |
| >.70 | |

Proj. 7597 IIb



Scale: 1"= 1000'
Location: SW 1/4 Section 14, T 2 S, R 67W
Land's wheatfield



Scale: 1"=500'
Location: NW 1/4 Section 17, T3S, R66W
Wheatfield south of arsenal

# GEOCHEMICAL MAP IIIgB

MAGNESIUM
in
B SOIL HORIZON (-80 Mesh)
ROCKY MOUNTAIN ARSENAL AREA
COLORADO

Scale: as noted
Base map from U.S.G.S. topographic maps

IntraSearch

Data prepared by Dr. Paul B. Trost
September 1976

EXPLANATION
$Mg_1$ %

| | |
|---|---|
| <0.41 | |
| .41-.55 | |
| .56-.70 | |
| >.70 | |

RSH 918



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PN 35 PD 1741752/1-100
FL Denver Plant